The Proposed Chuitna Coal Project: An Assessment of re-creating a functioning salmon-based ecosystem

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1 EXECUTIVE SUMMARY

A team of technical experts was assembled by the Chuitna Citizens Coalition and Cook Inletkeeper to review baseline information and relevant scientific literature to determine whether it is possible to re-create a functioning salmon-based ecosystem after a coal mine operation proposed by PacRim Coal, LP (PacRim) takes place in the Chuitna River watershed near Beluga, Alaska. An area of 20,571 acres has been leased to PacRim to explore for coal in the watershed of the Chuitna River. In the first stage of mining, PacRim plans to excavate up to 300 feet, and approximately 14 miles of salmon habitat in the Middle Creek channel will be destroyed. PacRim has stated that it can rebuild the salmon stream and return it to its pre-mining aquatic productivity level. PacRim has stated that it currently proposes to reconstruct (1) the anadromous spawning and rearing reaches of Middle Creek, (2) the riparian zones adjacent to the streams in the mining area, (3) the concentrated areas of peat deposits at the headwaters of the stream reaches, (4) open water ponds and lakes, and (5) wetlands affected by the mine footprint.[1] PacRim has not submitted a descriptive post-mining reclamation or restoration plan but has prepared a Fish and Wildlife Protection Plan, which states that PacRim will attempt to create a stream after all the natural aquifer flow paths and landscape topography have been eliminated.

This report summarizes the findings of the technical team and responds to three key questions for the project:

1. Can healthy, functioning aquatic systems be restored to the site?
2. Can the functions and services of lost aquatic ecosystems be mitigated elsewhere within the Chuitna River watershed?
3. Can the hydrologic system, including the ground water system, be restored to support re-creation of salmon streams?

The reviewers found:

1. Healthy, functioning aquatic systems cannot be restored.
2. The functions and services of lost aquatic ecosystems cannot be mitigated elsewhere within the Chuitna River watershed
3. The hydrologic system, including the ground water system, cannot be restored to support re-creation of salmon streams

Nothing comparable to re-creating an entire salmon-supporting watershed has been done to date. The scientific literature and world-wide experience suggests that re-creation of streams and wetlands, specifically peat wetlands, is not within the realm of current science. There is no evidence that such re-creation will be successful; in fact, there is extensive scientific evidence that less ambitious efforts to restore streams generally fail. Site hydrology will be totally disrupted from mining such that it cannot support headwater streams and wetlands. Peat that has been excavated and replaced will have lost the structural integrity upon which wetland hydrology is based, and will not likely function as wetlands that formed in response to changing natural conditions over millennia.

[1] *See* POA-2006-753 Draft Permit Application — Section 404/Section 10 Permit Application, PacRim Coal, LP, June 21, 2013, at 22, 34 and Sheet 17.

Opportunity for site restoration to offset the elimination of aquatic habitat from coal mining within the drainage is limited because other areas are presently undisturbed and functioning well. Further, much of the watershed is leased for coal mining. If such mining proceeds, mitigation for lost aquatic resources will be needed for these areas too.

Excavating, mixing and replacing 300 feet of subsurface materials, along with all aquifers that discharge to the surface, will fundamentally alter the hydrologic regimes at the site. Replaced material will be less dense so water will flow more rapidly through it. Aquitards that control the vertical movement of groundwater will be removed so that water will move lower in the system and likely discharge lower in surface streams.

Ecologically important headwaters will be eliminated. Headwater springs that exist prior to mining will not be re-established after mining. Salmon supporting hydrologic features of streams, such as upwelling and downwelling sites, will also be reduced or eliminated.

Coal mining in the watershed of Middle Creek in the Chuitna River system will not simply damage the ecosystem; it will remove the watershed: biota, water, and substrate. Throughout the analyses synthesized below a theme is repeated: the Chuitna mine site is a complex system that has not been adequately characterized for the task at hand. A great deal of uncertainty exists in the baseline conclusions about how the hydrologic system works and how it interacts with surface water, creating productive aquatic habitat. Without this information, planning for operation of the mine is based on unsupported assumptions, which if incorrect may cause additional unplanned, but nevertheless predictable, habitat degradation downstream of the mine on Middle Creek and in the mainstem of the Chuitna River.

Mitigating habitat losses and restoring the salmon ecosystem from this kind of intensive development would require that all the natural systems, including the processes that maintain them, be re-created from the essential elements. The experts engaged by the Chuitna Citizens Coalition and Cook Inletkeeper to review the Chuitna Coal Project information are leading experts on aquatic restoration. They have concluded that nothing similar to the type of restoration required for this Project has ever been successfully done. Experience from past efforts suggests that re-creation of a salmon producing ecosystem within the Chuitna River watershed will not be successful. In addition, proposals for restoration submitted to date for this site are vague, based on unsupported assumptions (such as unverified models) and lack the level of scientific and engineering detail expected in a proposal to attempt a restoration project of the magnitude that would be needed.

2 BACKGROUND

The Chuitna River and its tributaries are an important salmon producing drainage on the west side of Cook Inlet, Alaska. Much of the watershed has been leased for the extraction of its coal resources. Mining coal from the Chuitna River watershed will require excavation of drainages, including bedrock, to a depth of up to 300 feet. The proposed first stage of mining is in the Middle Creek watershed (Stream 2003) and includes mining directly through the upper reaches of Middle Creek and its tributaries, which are salmon-bearing streams. PacRim asserts that it will rebuild the landscape after coal extraction, including the reconstruction of 14 miles of salmon-bearing streams with headwaters and wetlands, to conditions that can support salmon at a level similar to existing populations.

2.1 Beluga Coal Fields

The Chuitna Coal project encompasses development of the Beluga Coal Fields, on the west side of Cook Inlet near the Alaska Native Village of Tyonek. The Beluga Coal Fields have been leased for coal development since the 1970s[2], but no coal has been commercially mined to date. An area of 20,571 acres has been leased to PacRim to explore for coal in the watershed of the Chuitna River. Additional coal leases in the Chuitna River watershed, upstream of the PacRim leases[3], are held by the Beluga Coal Company (owned by Barrick Gold and Cook Inlet Region, Incorporated[4]) (Figure 1). The thermal quality of the "coal" is very low, ranging from lignite to sub-bituminous rank[5, 6].

PacRim has identified three Logical Mining Units (LMUs) in four of the tributary watersheds to the Chuitna River, and on the river's mainstem (Figure 2). LMU 1, a 5,000-acre mining area, is proposed to be developed first). Coal would be excavated, crushed, transported to a stockpile near the Cook Inlet shore, and then conveyed on a trestle to a proposed ship loading dock approximately 2 miles offshore. There would be no water treatment of the coal before shipment[7].

LMU1 covers the entire upper watershed of Middle Creek (Figures 1 and 2). Surface mining will be completed in box cut swaths, beginning in approximately the middle of LMU1. Middle Creek runs through the middle of LMU1 and would be subject to the first box cut removals. The box cuts would work outwards from the middle of the LMU1 area. PacRim would backfill completed box cuts as mining progresses. Mining will temporarily remove overburden and permanently remove multiple seams of coal, leaving behind the clay, silt and sand that are interbedded with the coal[8]. The depth of excavation will be up to 300 feet. Based on recent estimates, approximately 14 miles[9] of salmon habitat in Middle Creek channel will be destroyed. Beyond these stream reaches, riparian habitat, peat wetlands and ecologically important headwaters where salmon have not yet been documented will also be destroyed. Mining will also extend into the two adjacent watersheds, Lone Creek (Stream 2002) to the east, and Stream 2004 to the west. Although the streambeds of these two creeks would not be excavated under the proposed plan, the hydrology and hydraulics of the streams would be significantly affected by mining of their watersheds and groundwater withdrawal and subsequent discharge to surface waters. These changes would seriously affect the nature of habitat within the streams.

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[2] PacRim Coal, LP. 2014. http://www.Chuitnacoalproject.com/background.html (last visited July 27, 2 0 1 4).

[3] Alaska Department of Commerce, Community and Economic Development. 2014. Beluga Coal Exploration Permit Application available at http://commerce.alaska.gov/CBP/Main/CorporationDetail.aspx?id=4631F (last visited July 28, 2014).

[4] Ibid.

[5] United States Environmental Protection Agency. 1990. Diamond Chuitna Coal Project: Final Environmental Impact Statement. EPA-10-AK-Chuitna-NPDES-90. Seattle, Washington. Section 4.4.1.

[6] The 1990 EIS notes coal has an average of 7,650 BTU/lb (USEPA. 1990. Final EIS Diamond Chuitna project. Pg S-2). According to a presentation made by PacRim Coal, LP in 2005 the heat content of Chuitna "coal" ranges from 7,650 Btu/lb to 8,800 Btu/lb and according to a 2007 presentation to regulators heat content averaged 7,498 Btu/lb (PacRim Coal, LP. 2005. "Development Status – Chuitna Coal Project." Presentation to Alaska Support Industry Alliance Kenai Chapter. Chuitna Coal Quality, Nov 22.; Mine Engineers, Inc. 2007. "Geology of the Chuitna coal project area." March 27). Lignite ranges from 4,500 Btu/lb to 8,500 Btu/lb. Sub-bituminous coal ranges from 8,300 Btu/lb to 11,500 Btu/lb. For simplicity we will refer to Chuitna material as coal in this report.

[7] PacRim. 2011. Applicant's proposed project. http://www.chuitnaseis.com/documents/Current-Project-Description.pdf (last visited November 24, 2014).

[8] Riverside. 2010. Chuitna coal project groundwater baseline report – Draft 1982 through September 2008. Prepared for PacRim Coal, Anchorage, Alaska. Pages 3-6.

[9] ERM. 2014. Fish Protection Plan, Chuitna Coal Project – Mine Area, Working Draft June 2014. Prepared in cooperation with PacRim Coal.

Mining LMU2 and LMU3 would occur at a later date (Figure 2); however, if infrastructure investments move forward to develop LMU1, coal mining in LMUs 2 and 3 can be anticipated. Development of infrastructure also increases the likelihood that the Beluga Coal Company will develop their coal leases. The analysis below focuses on LMU1 because that is the area of disturbance currently proposed by PacRim's 25-year mining plan and where baseline studies have been completed to date. However, it is unclear how the state and federal agencies can conduct an adequate NEPA review without data for LMUs 2 and 3, at a minimum.

Environmental data was collected at the site of LMU1 staring in the early 1980's, culminating in an Environmental Impact Statement (EIS) published by the EPA in 1990. Litigation followed state and federal permitting, coal markets softened, and the project did not move forward. In 2006, PacRim began an 18 month process to collect additional information to update environmental baseline information.

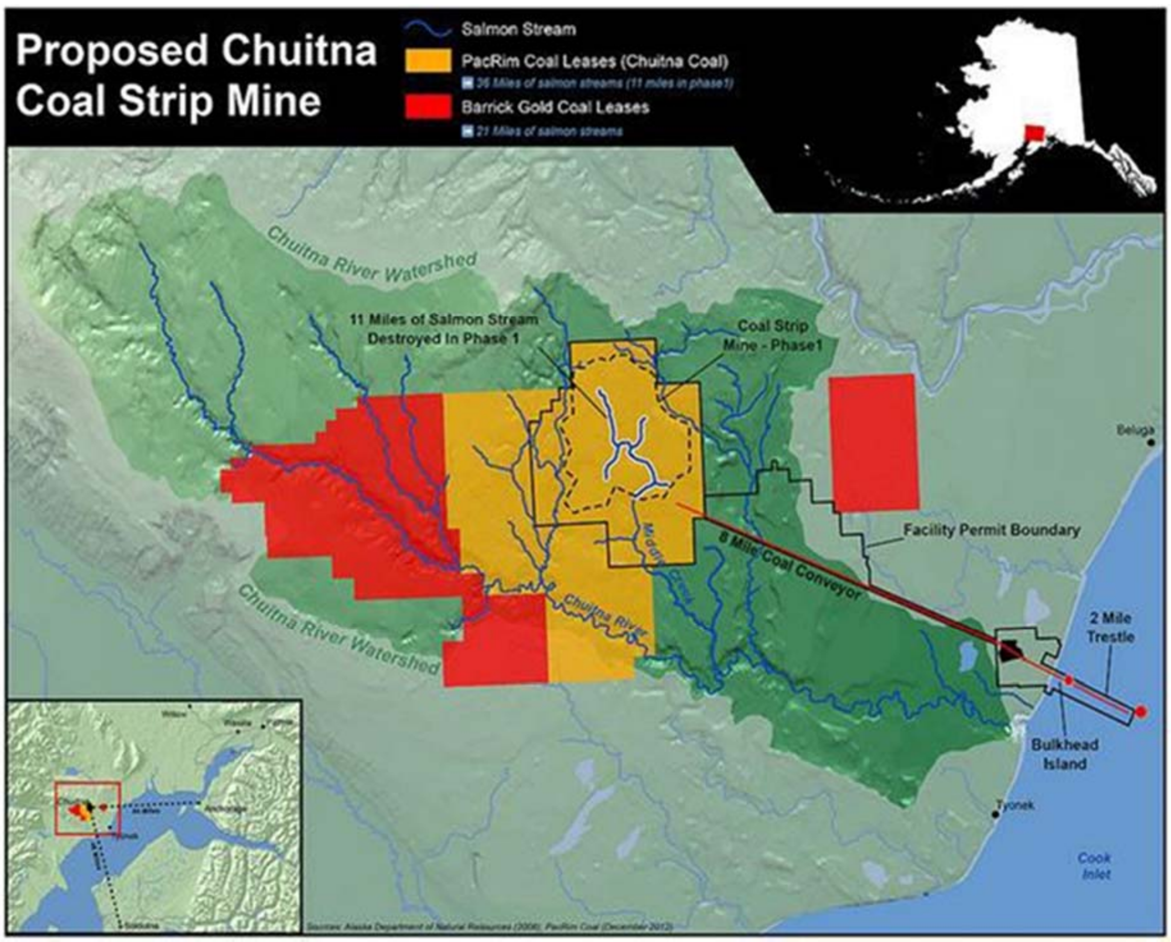

Figure 1. PacRim Coal, LP and Beluga Coal Company leases in the Chuitna watershed.[10]

[10] PacRim Coal, LP (Dec. 2012).

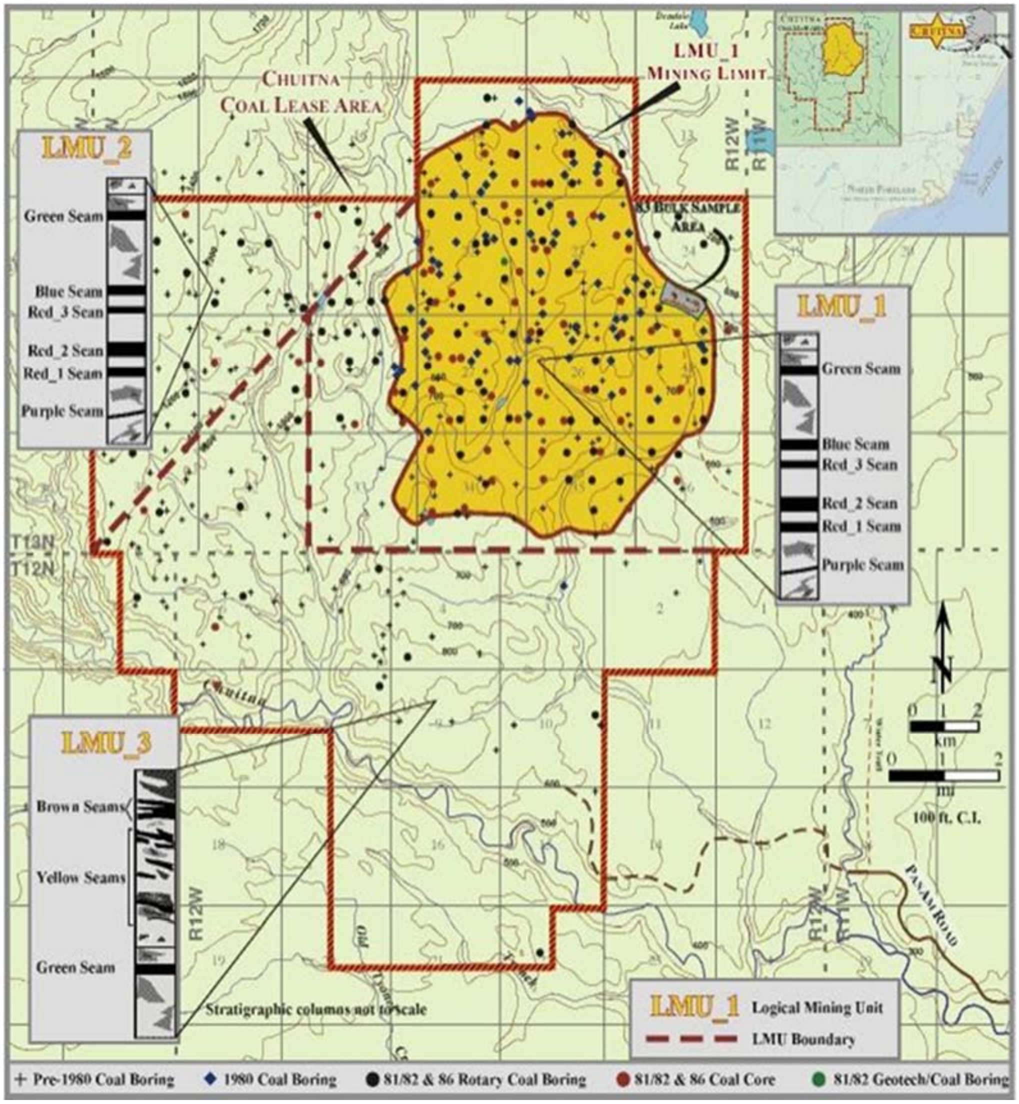

Figure 2. PacRim Coal, LP, lease area with three "Logical Mining Units" identified along with coal profiles.[11]

[11] PacRim. 2014

3 CONDITIONS AND EFFECTS

3.1 HYDROLOGIC RESOURCES

The hydrology of the Chuitna watershed is complex, incorporating surface waters of streams, ponds and wetlands (primarily peatlands) and a groundwater system of multiple aquifers. Each element contains its own internal structural complexity and interacts with others in ways that are key to the ecological integrity of this salmon-producing river system. The details of the complexity are important to the larger ecosystem, yet PacRim has failed to adequately characterize this complexity. Nor has PacRim described how the network of physical and biological processes interact to maintain healthy salmon/aquatic ecosystems. Characterizing the hydrogeology alone requires careful measurements to capture the highly dynamic processes that vary spatially and temporally. The nature and degree of disturbance caused by coal strip mining and the need to re-create the detailed structure of the components of the hydrogeology makes restoration of the system implausible.

3.1.1 Surface Water

3.1.1.1 River Systems

The Chuitna River is one of three major rivers in the Beluga Coal Fields, and the only one that is not glacial.[12] The Chuitna River tributaries within LMU1 are meandering streams with a typical gradient of about 1.2%, suitable for salmon spawning.[13, 14] Seasonal high flows occur from snowmelt in late April to June, and from rain in September and October. Low flow usually occurs in February, March or July. Streams are usually frozen, with some quantity of flow under the ice, from December to April.[15] As noted above, 14 miles of the salmon supporting reaches of Middle Creek and associated headwaters would be mined in the LMU1 mining area. Some of these headwaters have not been adequately surveyed for the presence of salmon and may be important salmon supporting waters.

A draft water management plan to control surface waters during and after mining has been developed for PacRim by Riverside Technologies, Inc.[16] The data supporting that water management plan is in question. Too many assumptions were made about the sources of river flow in terms of rainfall, evapotransporation and groundwater flow to confidently support the water management plan.[17] In spite of the long history of this project, climate and evapotransporation data was not collected. It is not clear why, but rainfall was back-calculated from runoff at a single stream gage. Not only was evapotransporation data not collected to account for site variability, it was not measured at the site at all. Instead, data was adjusted from a site 74 miles away, in a different climate in Palmer, Alaska.[18] The consequences of severe weather events were not considered in spite of four events during occurring

[12] Maurer, MA and DC Toland. 1984. Water quality data from the Beluga coal-field area, Alaska, June 1982-March 1983. Report of Investigation 84-27. Alaska Department of Geological and Geophysical Surveys. Fairbanks, AK.
[13] Montgomery, D. R., and J. M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. *Bulletin of the Geological Society of America* 109(5):596–611.
[14] Montgomery, D. R., E. M. Beamer, G. R. Pess, and T. P. Quinn. 1999. Channel type and salmonid spawning distribution and abundance. *Canadian Journal of Fisheries and Aquatic Sciences* 56(3):377–387.
[15] Riverside. 2009. Chuitna coal project surface water component baseline report – Final draft (1982) through September 2008. Prepared for PacRim Coal, Anchorage, Alaska. Pages 3-22 to 3-25 and Figure 7.
[16] Tetra Tech. 2013. Revised Draft Water Management Plan. Chuitna Coal Project. Prepared for PacRim Coal, LP.
[17] Myers. 2011. Baseflow conditions in the Chuitna River and watersheds 2002, 2003, and 2004 and the suitability of the area for surface coal mining. Page 20. Prepared for Cook Inletkeeper, Homer, Alaska. Page 15.
[18] Prucha, RH. 2013. Comments on the revised draft water management plan, Chuitna coal project (TetraTech, March 2013) and associated documents. Prepared for the U.S. Fish and Wildlife Service, Anchorage, Alaska. Pages 19 and 21.

since the original NEPA process. In addition, because of uncertainty in the data and poor characterization of the groundwater environment (see groundwater section, below), water balance was estimated indirectly. As a result, the water management plan contains unsupported assumptions. Management practices based on these assumptions may not work, with potential consequences if they do not.

Recent regional-scale scientific analysis of mining in the eastern and central United States showed that mining affects river systems far beyond the footprint of the mine. A 2014 study found that a single mine has the potential to alter fish assemblage throughout the stream draining that catchment.[19] As a result, river resources far beyond LMU1 must be considered when characterizing the river system and evaluating the impacts of mining.

3.1.1.2 Ponds

The hydrology of lakes and ponds has not been systematically characterized in baseline studies. Some ponds may be perched on impermeable materials above the water table while others may be hydrologically connected to groundwater. These aquatic resources are addressed in only a cursory fashion in restoration planning. Re-creation of ponds, an afterthought intended for consideration at some unspecified later date,[20] will be placed where unverified groundwater models show water intersecting the surface, ignoring the potential for different pond ecosystems being associated with the various existing hydrologic environments. For the most part, these aquatic ecosystems and the biodiversity and other aquatic functions that they provide will be lost.

3.1.1.3 Wetlands

Wetlands are an acknowledged but poorly characterized element of the hydrologic system.[21] Wetlands — primarily and significantly, peatlands — cover nearly half of the site.[22] They are important watershed elements biologically and hydrologically.

Many peatlands play a key role in regulating baseflow in streams, as well as in many other ecosystem processes.[23, 24] Recent research conducted by EPA's Mid-Continent Ecological Laboratory and the University of Minnesota, in cooperation with EPA Region 10, on Cook Inlet Basin wetlands shows that peatlands provide up to 55% of the baseflow in one stream supporting salmon.[25] Other recent research largely funded by EPA on the Kenai Peninsula demonstrates the important role of wetlands in headwater streams of the Cook Inlet Basin, which includes water temperature moderation, nutrient

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[19] Daniel, W.A, D.M. Infante, R.M. Hughes, Y.P. Tsand, P.C. Esselman, D. Wieerfich, K. Herreman, A.R. Cooper, L. Wang, W.W. Taylor. 2014. Characterizing coal and mineral mines as a regional source of stress to stream fish assemblages. Ecological Indicators 50, 50–61. Page 58.

[20] PacRim. 2014. Revised Post-Mine Reclamation Plan Overview Chuitna Coal Project. Prepared by PacRim Coal LP, with assistance from HDR Alaska, Inc. August 201

[21] Riverside, 2010.

[22] HDR. 2007. Chuitna Coal Project Baseline Report for Vegetation and Wetlands, 239 pg. For PacRim Coal LP 1007 West 3rd Ave, Suite 304 Anchorage, AK 99501.

[23] 22 Mitsch, W. J. and J. G. Gosselink. 2007. Wetlands. John Wiley and Sons, New Jersey.

[24] Walker, C.M, R.S. King, D.F. Whigham and S.J. Baird. 2012. Landscape and Wetland Influences on Headwater Stream Chemistry in the Kenai Lowlands, Alaska. Wetlands, Vol 31, No. 4.

[25] Gracz, M, M Moffett, D Siegel, and P Glaser. *In prep*. End – member mixing analysis in a homogenous watershed to identify the contribution of peatlands to stream flow.

processing and inputs to surface waters, physical habitat, and hydrologic and geomorphic influences.[26, 27, 28, 29, 30, 31, 32]

The role of wetlands in the ecological functions of the Chuitna River system is only superficially addressed in baseline studies.[33] It is not disputed that wetlands would be entirely removed by the mining process.

Peat has been accumulating for up to 14,000 years in the Cook Inlet Basin.[34, 35] Complex hydrologic properties within peat are produced by changing, including cyclic, environmental conditions.[36] Further complexity is added to the Chuitna peat by layers of volcanic ash,[37] including a thick layer deposited when Mt. Hayes erupted around 3750 years ago.[38] This structural complexity within the peat results in hydrology analogous to the description of glacial till included below, with layers of variable transmissivity.

Peat has a tremendous capacity to store water. Below the water table, around 90% of the peat mass is water.[39] Precipitation is far in excess of evapotranspiration at Chuitna, so peatlands must lose excess water or they would soon become completely submerged. The water loss, after evapotranspiration, can be flow either to surface or ground water. A key and uncharacterized element of surface water discharge is stream flow from wetlands.

As noted above, 89% of baseflow is attributed to groundwater discharge from glacial drift. However, it is likely that a significant portion of baseflow at the Chuitna site comes from peatlands. A comparison of water quality parameters between groundwater and surface waters indicated that ion concentrations in stream water is more dilute than groundwater, suggesting other contributions to baseflow than groundwater.[40] Some tracers, such as dissolved Ni, B, Pb, Ag, Cu, Al, Zn and total organic carbon, were

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[26] Callahan M, Rains M, Bellino J, Walker C, Baird S, Whigham D, King R. 2014. Controls on Temperature in Salmonid-Bearing Headwater Streams in Two Common Geomorphic Settings, Kenai Peninsula, Alaska. Journal of the American Water Resources Association. 15 pg.

[27] Dekar MP, King RS, Back JA, Walker CM, Whigham DF, Walker CM. 2012. Allochthonous inputs from grass-dominated wetlands support juvenile salmonids in headwater streams: evidence from stable isotopes of carbon, hydrogen, and nitrogen. Freshwater Science, 31(1):121-132.

[28] King RS, Walker CM, Whigham DF, Baird SJ, Back JA. 2012. Catchment topography and wetland geomorphology drive macroinvertebrate community structure and juvenile salmonid distributions in south-central Alaska headwater streams. Freshwater Science 31(2):341-364.

[29] Walker CM, King RS, Whigham DS. 2007. Wetland Geomorphic Linkages to Juvenile Salmonids and Macroinvertebrate Communities in Headwater Streams of the Kenai Lowlands, Alaska. Final project report to U.S. Environmental Protection Agency, Region 10.

[30] Walker CM, King RS, Rains M, Whigham DS, Baird SJ, Bellino J. 2009. Headwater Stream Wetland Settings and Shallow Ground Water Influence: Relationships to Juvenile Salmon Habitat on the Kenai Peninsula, Alaska. Final project report to U.S. Environmental Protection Agency, Region 10.

[31] Walker. 2012.

[32] Whigham DF, Walker CM, King RS, Baird SJ. 2012. Multiple Scales of Influence on Wetland Vegetation Associated with Headwater Streams in Alaska, USA. Wetlands 32: 411-422.

[33] HDR. 2013. Chuitna Coal Project Draft Wetland and Waterbody Functional Assessment Prepared for PacRim Coal LP 1007 West 3rd Avenue, Suite 304 Anchorage, Alaska 99501.

[34] Schmoll, H.R. & L.A. Yehle. 1987. Surficial geologic map of the northwestern quarter of the Tyonek A-4 quadrangle, South-Central Alaska. Interior, Geologic Survey, Reston VA. Page 198.

[35] Jones, M. C., D. M. Peteet, D. Kurdyla and T. Guilderson. 2009. Climate and vegetation history from a 14,000-year peatland record, Kenai Peninsula, Alaska. Quaternary Research, 72:207-217. Pages 210 and 213.

[36] 35 Watters, J. R. and E. H. Stanley. 2007. Stream channels in peatlands: The role of biological processes in controlling channel form. Geomorphology, 89:97-110. Pages 107 and 108.

[37] 36 Bands of volcanic ash from at least six eruptions are visible in profiles of different soil types, including peat soils and mineral soils (Ping, C-L and T Brown. 2007. Soil resources of Chuitna coal mine, Alaska. Report to DRven, Anchorage, Alaska).

[38] 37 Riehle, J. R., P. M. Bowers and T. A. Ager. 1990. The Hayes tephra deposits, and upper Holocene marker horizon in south-central Alaska. Quaternary Research, 33:276-290. Pages 280, 281 and Figure 3.

[39] 38 Clymo, R. S. 1983. Peat. In A.J.P.Gore (ed.), Ecosystems of the World 4A: Mires: Swamp, Bog, Fen and Moor, General Studies. Elsevier, Amsterdam. Page 167 and Figure 4.4.

[40] PacRim only lists data for a single well, 23T, as a "glacial drift" well in their 2010 report (Appendix B3, and 2010 Report Table 5-8). All wells are listed in Appendix B4, but the layer they are screened in is not listed. Instead, the hydrostratigraphic unit is listed in the 2010 report in Table 5-8. Note that although there are several wells listed as in the "glacial drift", nearly all were removed from 2007 baseline characterization because of bad data. The

not detectable in the drift aquifer, but were measurable in the stream water. A significant peatland source is strongly suggested by the relatively low conductivity and alkalinity, low concentrations of cations, higher organic carbon, and mobility of the trace metals in the stream.

Wetlands are therefore another source of hydrologic uncertainty at the mine site. Site-specific measurements need to be gathered pre-construction to educate water management and to include as metrics to establish whether the functions of re-created wetlands are restored (though the discussion below finds that wetlands that provide functions similar to those of extant wetlands cannot be re-created).

3.1.1.4 Summary of Surface Water Characterization Deficiencies

The baseline studies suggest a limited understanding of the controls on surface hydrology, which have complex spatial and temporal recharge and discharge.[41] In addition to deficiencies in groundwater data that relate directly to surface water (described below), there are important deficiencies in the characterization of surface water:

- Evapotranspiration measurements were used from a distant location (Palmer, Alaska 74 miles distant) with a substantially different climate. Given the long history of this project, it is curious that there are no evapotranspiration data on site;
- Long term climate data was not collected on site, introducing considerable error to water balance estimates and to the effectiveness of the water management plan;[42]
- Extreme weather events that result in severe flooding, such as have occurred at least four times since the original NEPA process was commenced, are not included in surface water analysis, introducing additional uncertainty to the water management plan and threat to downstream waters;[43]
- Inventories of seeps, springs, and surface-groundwater exchange, crucial for salmon habitat, are incomplete;[44]
- Flows into, out of, and within the system (i.e. boundary conditions) are inadequately described, and assumptions are not justified with proper characterization. This is especially true for on-site faults and groundwater discharge from lower geologic strata, which must be adequately dewatered during mining;
- The basis used for including or excluding data from particular wells is not clear from the hydrology reports. Without more information, it is impossible to determine the validity of water levels from wells included in the baseline characterization;
- The hydrology of ponds is not characterized and their variability is ignored; and
- The role of wetlands in surface water balance is not considered in the water management plan.

It is worth restating that the lack of reliable data introduces considerable uncertainty in the water management plan, which undermines the ability to design effective mitigation measures related to water flow. The consequences of errors are, at a minimum, diminished habitat value, and at worst, degraded stream channels where habitat is destroyed for some distance downstream of the disturbance.

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remaining wells were 3 with data from 1982, and a single well with post-2006 data. TetraTech has decided to not use pre-2006 data. This leaves only a single drift well with good data, which is insufficient for groundwater quality characterization or comparison with stream water quality. This data needs to be supplemented to adequately understand site hydrology.

[41] Prucha. 2013. Page 31.

[42] Ibid. Pages 3, 4 and 16.

[43] Myers. 2009.

[44] The inventories are described in Oasis 2010 and critiqued in Prucha 2013, pages 6-7, 18, 31-33.

3.1.2 Groundwater

Groundwater at LMU1 is described in PacRim's baseline studies as two flow systems, which can in turn be described as four aquifers. These units perform functions of storing water (recharge), moving water (transmissivity), and releasing water (discharge) to the other groundwater systems and to the surface. The upper flow moves through the alluvial and glacial drift aquifer systems, and the lower flow moves through the coal sequence aquifer and, beneath the coal sequence, the Sub Red 1 Sand aquifer. The alluvial aquifer averages 40' thick, glacial drift is 40'-140' thick, and multiple coal seams range 4'-33' thick, interbedded with silt, clay and sand layers.[45] The coal sequence, composed of multiple coal seams and interbedding, is up to 300 feet thick.[46] A key characteristic of site lithology is that none of the units are homogenous.[47] Layers of clay, silt, and sand control water movement within these primary aquifers in ways that influence surface water ecosystem functions. Storage and discharge are also affected by the connectivity between the aquifers and by the two fault systems on the boundaries of LMU1.

3.1.2.1 Alluvial Aquifers

An alluvial aquifer is essentially an extension of the stream under the channel and flood plain. It is a zone of exchange between groundwater and the stream surface flow systems. An alluvial aquifer plays many roles in the ecological functioning of a stream, including temperature regulation, nutrient processing, and habitat for stream biota.[48] Except to document that upwelling occurs, no characterization of stream-groundwater interactions has been done.[49] The modeled hydraulic properties show little correlation to the properties that would be expected based on USGS surficial geology maps.[50] The hydrologic conceptual model used by PacRim to describe the movement of water in these systems does not include a description of the interaction of aquifers between the sedimentary layers and alluvium.[51] As with glacial drift and seismic faults (discussed below), without an understanding of the flow of water through these systems, essential goals for re-creating these systems cannot be established.

3.1.2.2 Glacial Drift Aquifers

Glacial drift is composed of (1) till that has been deposited directly from the melting glacier and (2) glaciofluvial deposits that have been sorted by flowing melt water. Glaciofluvial deposits form clay, silt, sand and/or gravel layers among the accumulation of till. The layers have various levels of permeability, dictated by particle size. Layers made of fine particles have low permeability and form aquitards that reduce vertical flow within the relatively permeable glacial till, forcing groundwater to flow horizontally.

Layers of course sediment provide conduits for ground water movement. PacRim's baseline studies acknowledge the complex layering of the glacial drift, but do not reflect an understanding of the layers that control the vertical and horizontal movement of water within this system, nor interaction of glacial drift groundwater with surface water systems.

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[45] Riverside, 2010, pages 3-8.
[46] Ibid, pages 4-5.
[47] Seventeen drill holes in the glacial drift reported 4-19% clay, 13-52% silt, and 5-45% "coarse fragments" (MEI 2007, as reported by Myers 2011a, pg 5).
[48] Boulton, A.J., L.S. Findlay, P. Marmonier, E.H. Stanley and H.M. Valett. 1998. The functional significance of the hyporheic zone in streams and rivers. Annual Review of Ecology and Systematics, Vol. 29: 59-81
[49] Prucha, 2013, pages 7, 13, 23, 32 and 38.
[50] Ibid, page 14.
[51] Myers, 2012. Review of the Chuitna Coal Project hydrological conceptual model. Prepared for Cook Inletkeeper, Homer, Alaska.

Where layers intersect the surface, such as along Middle Creek, groundwater discharge may create springs, wetlands, and upwelling areas in streams. Most recharge enters the system from glacial drift, through alluvium to streams.[52] In this manner, glacial drift is important in distributing groundwater throughout the watershed and, through upwelling in streams, allows groundwater to contribute to critical spawning and rearing sites for fish, including salmon.

Sites of upwelling and downwelling in streams are critical habitat features for stream fish. These sites aerate salmon eggs during incubation and provide unfrozen habitat for juvenile salmon that overwinter in the streams. During the summer they provide a source of cool water. This flow of groundwater into the stream is baseflow during dry periods.

Eighty-nine percent of baseflow is attributed to flow from the glacial drift[53] (however, see the discussion below on wetland contribution to baseflow). Layering within the glacial drift controls the temporal and special behavior of most of the site's groundwater. Poor or no characterization of these features results in an inability to mitigate effects of mine development.[54]

3.1.2.3 Geologic Faults and Impacts to Groundwater Movement

Two faults, the Chuit Fault in the north and the South Pit Fault in the south, pass through the proposed mine site. They are offset vertically 100 to 300 feet, with the area between them having dropped down so that layers of sediment making up the aquifers do not align across the faults.[55] The faults have the potential to facilitate or retard groundwater movement on and off site. Because they have not been adequately characterized, however, there is limited understanding of how groundwater reacts to the faults,[56] retarding or facilitating flow. Mining will remove the layers that meet at the faults and replace them with material that has been mixed through handling. Without a better characterization, it is not possible to know how groundwater behavior will change in these areas. As a result, it is not possible to responsibly prepare for mine water management or to establish goals for re-creating the site hydrology.[57, 58, 59]

3.1.2.4 Coal Seam Aquifer

Of the two aquifers that make up the lower flow system, the coal sequence is said to store about 11% of the water in the groundwater system of the site.[60] Although the coal aquifer is part of the deep flow system, receiving water from deep aquifers off-site, well data shows that it responds to seasonal events and performs both storage and discharge functions. For example, where glacial drift has been eroded along some stream reaches, coal seams are exposed and discharge to surface waters.[61] A better understanding is needed of the role of the coal seam aquifer in stream baseflow.

[52] Myers. 2011.
[53] USEPA. 1990. Pages 4-24 and 4-25.
[54] Prucha. 2013. Page 23.
[55] Riverside, 2010, page 3-7.
[56] Ibid, page 4-22.
[57] Prucha, 2013, page 24 and Table E1.
[58] Myers, T. 2012. Pages 2, 3 and 5.
[59] Hecht, 2009, pages 12, 13 and 19.
[60] United States Environmental Protection Agency. 1990. Diamond Chuitna Coal Project: Final Environmental Impact Statement. EPA-10-AK-Chuitna-NPDES-90. Seattle, Washington. Section 4.4.1.
[61] Riverside, 2010.

3.1.2.5 Sub Red 1 Sands Aquifer

The lowest aquifer described in the baseline information, the Sub Red 1 Sand, is artesian. In many places in the watershed, but not everywhere, it is separated from the overlying coal by low-permeability silt or clay. The thickness and extent of the clay "cap" and the presence of fractures through the cap have not been characterized, but could have a large influence on groundwater movement when the overlying coal is removed.[62]

Unanticipated flow from this artesian system to a mine pit would result in excess water with significant implications for water management on the site. Flow from this system should be anticipated, but is not adequately addressed in baseline studies.

3.1.2.6 Summary of groundwater hydrology baseline deficiencies

The picture that emerges is of a complicated hydrologic system. Alluvium, drift, coal sequences, and the sand units all represent groundwater units. Significant data gaps lead to a high level of uncertainty of how groundwater behaves within these systems. Such uncertainty invalidates the draft water management plan,[63] and assumptions on water availability in mitigation plans. Incorrect assumptions may have severe consequences. Data gaps include:

- There is an insufficient understanding of the hydrologic effect of complicated layering of the glacial drift and its role in supporting fish habitat in streams;
- At the Chuit and South Pit faults, a lack of knowledge of hydrology could lead to unpredicted flow of water during and after mining with unknown consequences;
- Hydraulic conductivity through faults and the locations of outcrops and springs will also influence groundwater flow, but are incomplete in PacRim's baseline analyses;
- Insufficient understanding exists regarding hydrologic communication between Sub Red 1 Sand and overlying coal seams;
- Without understanding the complex structure of the glacial drift and coal sequences and the compaction provided over millennia, water flow through the homogenized backfilled material will be different and unpredictable. Water may drain faster vertically, retaining less water in the upper flow system, affecting the timing, quantity and aerial extent of surface flows. Headwater streams and wetlands may be eliminated altogether;
- Lack of adequate sensitivity testing on data has also added to the high level of uncertainty for modeling that would otherwise provide insight into how groundwater is behaving at the site.[64] This high level of uncertainty offers little confidence that a groundwater environment can be re-created so that it supports a salmon-based ecosystem; and
- The development of multiple groundwater flow models is currently standard practice, especially in complex systems. Thus, using only one model may be the largest source of uncertainty generated in PacRim's conceptualization of groundwater systems.[65]

Without special sorting and mapping of materials within these strata it will be impossible to re-create this complexity following mining, which is a critical element in the expression of habitat and other functional features in surface waters. An extensive search of the scientific literature indicates there is no evidence that re-creating such a complex hydrologic system has been or can be done.

[62] Prucha 2013, page 22.
[63] Tetra Tech. 2013.
[64] Prucha, 2013, pages 5 and 33.
[65] Prucha. 2013.

3.2 Fish and Aquatic Habitat

Unlike current coal producing areas of Alaska, the Chuitna River is located in a productive coastal ecosystem that supports a diversity of fish and wildlife species. Surveys by the State of Alaska in the early 1980s indicated high water quality and healthy aquatic communities.[66]

The Chuitna watershed supports all five species of pacific salmon (Oncorhynchus sp.) as well as Dolly Varden (Salvelinus malma), rainbow trout (Oncorhynchus mykiss) and whitefish (Coregonus sp.)[67]. Chuitna River salmon are harvested by the Northern District commercial fishery and the Tyonek Village subsistence fishery and an in-river sport fishery.[68] On the west side of Cook Inlet, the Chuitna River sport fishery for Chinook salmon (Oncorhynchus tshawytscha) has historically been second in importance only to the Deshka River. Because of this importance and the overall general decline of Chinook salmon returns in Cook Inlet, the Chuitna River Chinook stock was listed as a stock of management concern by the Alaska Board of Fisheries in 2010.[69]

Our scientific review found critical omissions from the documents prepared by PacRim characterizing the salmon fishery and aquatic habitat in the proposed Chuitna Coal mine area. The document fails to address food webs, trophic linkages, linkages between upstream-downstream reaches, surface water-groundwater, stream-riparian, stream- marine, and basin-wide linkages (below and above ground). The past 20 years have seen significant improvements in our general understanding of aquatic ecosystem function and the baseline report omissions severely undermine the ability of the mining plans to protect ecosystem function during mining and to re-create it post-mining.[70]

Study findings between the 1980's and 2006-2008 are markedly different. It is unclear if these differences are the result of changes in species composition, numbers and life history or differences in methodology. For example, the data suggest that the spawning adult salmon abundance counted and their timing appears to have changed between these two time periods. One reason could be that the spawning count ceased on September 30 in 2008 in spite of 1980s documentation of spawning until late October.[71] The lack of consistent, long-term sampling confounds interpretation of the data and precludes the needed estimate of annual biological variability or range of variability, and does not provide a suitable reference baseline condition to which post-mining rehabilitation effects can be compared.[72]

Summary of deficiencies of the baseline fish and aquatic habitat studies include:

- Food webs: Noticeably missing from the existing baseline studies and restoration plans in the Chuitna system is an understanding of food webs, trophic processes, and their dynamics. The

[66] Maurer, MA. 1986. Chemical and biological water quality of selected streams in the Beluga coal area, Alaska. Public data file 86-51. Alaska Division of Geological and Geophysical Surveys. Fairbanks, AK.
[67] ADFG (Alaska Department of Fish & Game). 2014. Catalog of Waters Important for the Spawning Rearing and Migration of Anadromous Fish. www.adfg.gov/sf/SARR/AWC accessed on August 5, 2014.
[68] Holen,D. and J. Fall. 2011. An Overview of Subsistence Salmon Fisheries in the Tyonek Subdistrict and Yetna River, Cook Inlet Alaska. www.adf&g.gov/sub/
[69] Alaska Board of Fisheries. 2011. Findings regarding regulatory action taken to address salmon stocks of concern in the Upper Cook Inlet Area. 2011-266-FB. March 26, 2011.
[70] Wipfli, M.S. 2009. Chuitna Coal Mine baseline monitoring and restoration plan review. For Inletkeeper, Homer, Alaska.
[71] Trasky, L. 2009. Report on Chuitna Coal Project Aquatic Studies and Fish and Wildlife Protection Plan. For Inletkeeper, Homer, Alaska.
[72] Wipfli. 2009. Page 2.

flow of nutrients, detritus, and prey to and through food webs has been well studied in recent years by the scientific community, and it is clear that food web complexity and productivity in part drives fish and other aquatic consumer populations;[73, 74]

- Watershed scale perspective: Baseline studies do not reflect a clear understanding of watershed-wide processes, linkages, and interactions which are key to understanding what drives ecosystem productivity including fish populations. This is a central part of understanding ecosystem function and its restoration in the Chuitna system;

- Off-channel-stream linkages: Habitats such as wetlands, ponds (including beaver ponds), remnant oxbow channels, etc., are important rearing, overwintering, and foraging areas for fish.[75] Understanding the role/function of these off-channel habitats is crucial to a broader understanding of watershed function, yet these analyses have not occurred and adequate studies of these habitats have not been undertaken;

- Riparian-aquatic linkages: Understanding the process of energy flow between the stream and riparian habitats is crucial in the Chuitna system. For example, energy flow from streams to riparian vegetation which are consumed by riparian consumers such as birds and invertebrate predators, and, in reverse, of terrestrial prey flow from riparian habitats to streams as a source of prey for fish. Knowing how the current plant community affects trophic pathways and food supplies that flow from riparian habitats to streams is essential to more fully understand how this particular trophic process is driving fish populations in the Chuitna system currently, yet these analyses have not occurred;

- Headwater-stream linkages: Ecological linkages between headwater streams and larger-order rivers are better understood today than previously, and a growing body of literature indicates that headwaters are crucial for sustaining the structure, function, productivity and biocomplexity of the downstream river ecosystems into which they flow.[76] Headwater streams provide downstream habitats with a multitude of ecosystem services, including water, nutrients (e.g., nitrogen and phosphorus), food (e.g., organic matter and invertebrate prey for fish and insectivorous birds), and wood that provides structural habitat for biota.[77, 78, 79, 80] Headwater streams also serve as refugia, spawning habitats, and source areas for biodiversity.[81, 82] The baseline studies fail to assess, consider or otherwise address the linkages between the headwaters of Stream 2003 and the Chuitna River; and

[73] Polis, G. A., M. E. Power, and G. R. Huxel. 2004. Food Webs at the Landscape Level. University of Chicago Press, Chicago, USA.
[74] Wipfli, M.S., and C.V. Baxter. 2010. Linking ecosystems, food webs, and fish production: Subsidies in salmonid watersheds. Fisheries 35(8): 373-387.
[75] Limm M.P. and M.P. Marchetti. 2009. Juvenile Chinook salmon (Oncorhynchus tshawytscha) growth in off-channel and main-channel habitats on the Sacramento River, CA using otolith increment widths. Environ Biol Fish (2009) 85:141–151
[76] Haigh, M. J., R. B. Singh, and J. Krecek. 1998. Headwater control: matters arising. *In* Headwaters: Water Resources and Soil Conservation. M. J. Haigh, J. Krecek, G. S. Rajwar, and M. P. Kilmartin, editors. A.A. Balkema, Rotterdam, Netherlands. pp. 3- 24
[77] Wipfli, M.S., and D.P. Gregovich. 2002. Export of invertebrates and detritus from fishless headwater streams in southeastern Alaska: implications for downstream salmonid production. Freshwater Biology. 47: 957-969.
[78] Compton, J. E., M. R. Church, S. T. Larned, and W. E. Hogsett. 2003. Nitrogen export from forested watersheds in the Oregon Coast Range: the role of N2-fixing red alder. Ecosystems 6:773-785.
[79] Gregory, S. V., K. L. Boyer, and A. M. Gurnell (Editors). 2003. The Ecology and Management of Wood in World Rivers. American Fisheries Society Symposium 37, Bethesda, Maryland.
[80] Wipfli, M.S., J.S. Richardson, and R.J. Naiman. 2007. Ecological linkages between headwaters and downstream ecosystems: transport of organic matter, invertebrates, and wood down headwater channels. Journal of the American Water Resources Association 43: 72-85.
[81] Bramblett, R. G., M. D. Bryant, B. E. Wright, and R. G. White. 2002. Seasonal use of small tributary and main-stem habitats by juvenile steelhead, coho salmon, and Dolly Varden in a southeastern Alaska drainage basin. Transactions of the American Fisheries Society 131:498-506.
[82] Meyer, J. L., D. L. Strayer, J. B. Wallace, S. L. Eggert, and G. S. Helfman. The contribution of headwater streams to biodiversity in river networks. Journal of the American Water Resources Association 43:86-103.

- Marine-freshwater linkages: Strong ecological linkages connect marine systems and watersheds via runs of anadromous fishes (e.g., salmon), and these linkages have been shown to be essential to the long-term productivity and sustainability of riverine function, nutrient supply and storage, and food web and fish productivity.[83, 84, 85, 86] These linkages remain strong in Alaska due to the healthy runs of salmon, but loss and degradation of riverine habitat can severely impact these linkages. In the Pacific Northwest, suppressed salmon runs have led to severe nutrient deficits, leading to reduced freshwater productivity and serious problems with attempts to restore salmon and their ecosystems.[87] The baseline studies fail to assess, consider or otherwise address the linkages between Stream 2003 and the Chuit River with Cook Inlet marine waters.

4 RESTORATION

PacRim and the State of Alaska have provided several examples of projects that have attempted to enhance or restore aquatic habitat value to support the proposed project. However, there are critical differences between the examples presented and the Chuitna Coal Project. Specifically, all examples describe efforts to repair a damaged ecosystem where the underlying hydrologic processes remain intact. In the case of the proposed Chuitna Coal Project, the entire system will be removed, including bedrock and all aquifers that interact with the surface. Re-creating a surface morphology that interacts with existing hydrologic systems is critically and substantially different from attempting to re-create an entire watershed system. However, even the relatively straightforward attempts to restore aquatic habitat where the hydrologic processes remained intact have been largely unsuccessful at restoring ecosystem function.[88]

4.1 GROUNDWATER RESTORATION

If the original hydrologic functions are to be restored, then coal sequence inter-burden, glacial drift and alluvium must be backfilled in a manner similar to what existed before mining — baseflow must be adequate to support salmon populations during periods when there is no water flowing into the stream from the ground surface (mid- winter and during summer dry periods); upwelling and downwelling areas must be created; the post mining hydrograph must closely resemble the pre-mining hydrograph to link to the timing of biotic cycles. It is not enough to re-create one or a few layers of low conductivity material in the backfilled material. Site hydrology derives, in part, from complex layering within each of

[83] Naiman, R. J., R. E. Bilby, D. E. Schindler, and J. M. Helfield. 2002. Pacific salmon, nutrients, and the dynamics of freshwater and riparian ecosystems. Ecosystems 5:399-417.
[83] Wipfli, M.S. & Musslewhite, J., 2004. Density of red alder (Alnus rubra)

[85] Naiman, R. J., R. E. Bilby, D. E. Schindler, and J. M. Helfield. 2002. Pacific salmon, nutrients, and the dynamics of freshwater and riparian ecosystems. Ecosystems 5:399-417.
[86] Wipfli, M.S. & Musslewhite, J., 2004. Density of red alder (Alnus rubra) in headwaters influences invertebrate and organic matter subsidies to downstream fish habitats in Alaska. *Hydrobiologia*, 520, pp.153–163.
[87] Gresh,T, J, Lichatowich, and P. Schoonmaker. 2000. Salmon Decline Creates Nutrient Deficit in Northwest Streams. www.inforain.org/reports/salmon-decline.html. 10p
[88] Palmer, M.A. 2009. Report on Chuitna Coal Project of PacRim Coal. For Inletkeeper, Homer, Alaska.

the pre-mining aquifers. All of these layers of gravel, sand, silt and clay must be understood and emulated to successfully re-create habitat complexity in the streams.

Backfilled material will be less dense than pre-mining geologic strata and layers of silt and clay that slowed the vertical movement of water in the glacial drift will have been mixed with coarser material. Thus, backfill material will lack the complex structure that disseminates groundwater discharge throughout the watershed. We can logically predict that the vertical movement of water will accelerate the discharge of groundwater low in the watershed, possibly eliminating flow from headwater streams and wetlands for much of the year. In addition to direct loss of habitat, loss of headwaters would result in the loss of the functions described in the discussion of wetlands (Section 3.1.1.3) above, adversely affecting downstream waters.

4.2 STREAM RESTORATION

As discussed above, surface waters are integrally tied to the patterns of groundwater discharge. Successful restoration cannot be defined as water flowing through a re-created channel. Surface waters must have the complex relationship with groundwater previously described so surface runoff, baseflow and habitat features, such as upwelling and downwelling, are in place and functioning. These detailed surface/subsurface hydraulic interactions also drive microbial and chemical processes all along the flow paths that create the biogeochemical conditions that support healthy foods webs.

As described in the Fish and Wildlife Protection Plan[89], PacRim will attempt to create a stream after all the natural aquifer flow paths and landscape topography have been eliminated. This is not in the realm of anything that has been scientifically tested and is certainly not within the realm of what is considered ecological restoration. In practice, ecological stream restoration varies along a continuum from: removing on-going impacts to a stream (e.g., preventing toxic inputs) and letting the system recover naturally; to enhancing in-stream habitat or the surrounding riparian zone (e.g., adding coarse woody debris to streams and planting vegetation) in an otherwise healthy stream; to full scale restoration that involves manipulations of an existing stream channel (e.g., re- grading banks and planting trees along a stream with eroding banks, for example Resurrection Creek, Alaska))[90]. The practice has not progressed to building a complete salmon based landscape.

Research shows that attempts to create streams de novo or even create channels where the watershed has been totally disrupted as in the proposed PacRim project have not resulted in streams that support the biodiversity or ecological processes characteristic of nearby intact streams.[91] Studies evaluating projects on reclaimed mine land using ecological standards concluded that created streams on mine land do not mimic natural streams[92] and do not produce biological outcomes comparable to un-impacted reference streams[93]. Currently, there are no scientifically validated methods for constructing a

[89] PacRim,PartD7, Draft ASCMCRA Application, Fish and Wildlife Protection Plan, July 2007.
[90] Palmer, 2009.
[91] Jones, N.E, G.J. Scrimgeour, and W.M. Tonn. 2008. Assessing the Effectiveness of a Constructed Arctic Stream Using Multiple Biological Attributes Environmental Management 42:1064–1076
[92] Petty, J. T.; Gingerich, G.; Anderson, J. T.; Ziemkiewicz, P. F. Ecological function of constructed perennial stream channels on reclaimed surface coal mines. *Hydrobiologia* 2013, *720*, 39–53.
[93] Fritz, K. M.; Fulton, S.; Johnson, B. R.; Barton, C. D.; Jack, J. D.; Word, D. A.; Burke, R. A. Structural and functional characteristics of natural and constructed channels draining a reclaimed mountaintop removal and valley fill coal mine. *J. North Am. Benthol. Soc.* 2010, *29*, 673–689; Jones, N. E.; Scrimgeour, G. J.; Tonn, W. M. Assessing the effectiveness of a constructed Arctic stream using multiple biological attributes. *Environ. Manage.* 2008, *42*, 1064–1076; Scrimgeour, G.; Jones, N.; Tonn, W. M. 2011. Benthic macroinvertebrate response to habitat restoration in a constructed Arctic stream.

stream in an area that did not formerly have one (or where the entire watershed has been excavated) and the feasibility of doing this has been challenged by the scientific community[94] and the Corps and EPA, who discourage stream creation in the 2008 Compensatory Mitigation rule.[95]

One of our team members led a national project which developed the first comprehensive database of 38,000 stream and river restoration projects within the U.S.[96, 97] There is not a single project case which provides evidence that restoring the streams in the manner outlined by PacRim in its Fish and Wildlife Protection Plan will be successful. Contrary to suggestions made in the mitigation plans, the very concept of creating streams with levels of ecological function comparable to natural channels on sites that have been mined-through remains untested and highly unlikely to succeed.[98] This was confirmed by an extensive evaluation of stream mitigation projects permitted for mining, where 100 projects with at least 3 years of post-construction data exhibited no ecological recovery. In fact, with respect to habitat, more than 97% of the projects were marginal or suboptimal, with created streams exhibiting the highest failure rates.[99]

4.3 Peatland Restoration

The scientific literature on peatland restoration tends to address one of three conditions:

(1) peat was removed for fuel or Sphagnum moss for gardening, but the underlying hydrology was not affected (e.g. Ireland, Canada and northern Europe),

(2) peat was removed down to glacial till material (e.g. Colorado) and

(3) peat was removed to access tar sands (Canada).

As with other types of restoration, peatland restoration has only been attempted at sites where the surface is disturbed but the underlying landscape and its aquifers are intact and functioning. In most cases some peat remains intact at the site and rewetting of existing peat by blocking drainage ditches is the primary method of restoration.[100, 101, 102, 103, 104] There is no indication in the scientific literature that anyone has ever attempted to create a peatland following complete removal, let alone an entire functioning landscape of interconnected peatlands, streams and groundwater.

Although one recent numerical model suggests that it is theoretically possible to configure a hypothetical slice of the surrounding landscape to adequately sustain peat wetness through a dry

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[94] Palmer, M. A.; Filoso, S. Restoration of ecosystem services for environmental markets. *Science* 2009, *325*, 575–576; Bronner, C. E.; Bartlett, A. M.; Whiteway, S. L.; Lambert, D. C.; Bennett, S. J.; Rabideau, A. J. An Assessment of U.S. Stream Compensatory Mitigation Policy: Necessary Changes to Protect Ecosystem Functions and Services. *JAWRA J. Am. Water Resour. Assoc.* 2013, *49*, 449–462.

[95] ACOE; EPA. Compensatory Mitigation for Losses of Aquatic Resources: Final Rule. *Fed. Regist.* 2008, *73 Fed.*, 19593–19705, at 19596.

[96] Bernhardt, E, and M. Palmer. 2011. River restoration: The fuzzy logic of repairing reaches to reverse catchment scale degradation. Ecological Applications. 21(6)2011, pp 1926-1931.

[97] Palmer, M. A., E. Bernhardt, J. D. Allan, and the National River Restoration Science Synthesis Working Group (2005) Standards for ecologically successful river restoration, J. Appl. Ecol., 42, 208–217.

[98] Palmer 2009.

[99] Palmer, M.A., K. Hondula. 2014. Restoration as mitigation: analysis of stream mitigation for coal mining impacts in southern Appalachia. Env. Sci & Technology 48: 10552-10560.

[100] Schimelpfenig, DW, DJ Cooper and RA Chimner. 2013. Effectiveness of ditch blockage for restoring hydrologic and soil processes in mountain peatlands. Restoration Ecology 22 (2): 257-265.

[101] McCarter, CPR and JS Price. 2013. The hydrology of the Bois-des-Bel bog peatland restoration: 10 years post-restoration. *Ecological Engineering* 55:73-81.

[102] Holden, J, ZE Wallage, SN Lane, and AT McDonald. 2011. Water table dynamics in undisturbed, drained, and restored blanket peat. *J Hydrol* 402 (1-2): 103-114.

[103] Kozulin, AV, NI Tanovitskaya, IN Vershitskaya. 2010. Methodical recommendations for ecological rehabilitation of damaged mires and prevention of disturbances to the hydrologic regime of mire ecosystems in the process of drainage. Scientific and Practical Center for Bio Resources, Institute for Nature Management of the National Academy of Sciences of Belarus.

[104] Price, JS and SJ Ketcheson. 2008. Water relations in cutover peatlands: Carbon cycling in northern peatlands. Geophysical Monograph Series 184, American Geophysical Union. pp 277- 287.

growing season in Alberta, Canada, no methods are proposed to harvest, store and deliver the peat to the configured landscape without destroying the hydraulic properties of the peat.[105] These properties are required to create a functional peat-accumulating system. The model investigates only a single element of a much larger equation for restoration.

There are a number of factors favoring and opposing the success of peatland restoration.[106] Factors favoring success are absence of permafrost and few if any invasive species. Opposing factors are sloping topography, absence of vegetation and seed bank, complex hydrology, lack of connections to other peatlands, presence of rare species, and distance to appropriate propagule sources. These factors apply when remnant peat is present on the original landform; however, peat at the Chuitna site will be completely removed, as will the underlying landforms.

Sites with alterations to the surrounding landscape, such as the altered site hydrology that is likely to occur at Chuitna, may no longer support peatlands, or any wetland.[107]

However, even in a relatively undisturbed landscape some restoration practitioners have asserted that re-establishment of a peat producing system will only be possible where a layer of peat remains;[108] 50 cm of undisturbed peat has been reported as a minimum threshold.[109] Once peatlands have lost so much peat by mining, erosion or oxidation, however, restoration of a self-regulating peat wetland has become impossible because subsidence, compaction, fissuring, decomposition and mineralization change the porosity, storage coefficient, hydraulic conductivity, and capillarity of the peat in a largely irreversible manner. Compacted peat prevents water from re-entering the peat body, and the decreased storage coefficient of compacted peat leads to larger water level fluctuations, which increase decomposition leading to peat soils that eventually become "un-rewettable."[110] Excavating, hauling and stockpiling peat will inevitably result in the disturbances described above. Experience of published practitioners suggests that restoration of peat wetlands will not be possible. Peat wetland functions and services, perhaps most notably the role in providing adequate baseflow for salmon production, will be lost.

4.4 Salmon Ecosystem Restoration

To re-create a productive watershed that supports salmon spawning and rearing in the post-mined areas of the Chuitna River watershed, a complex ecosystem must be constructed which incorporates:

(1) a vegetated, appropriately contoured, watershed that controls the quantity and quality of surface and ground water flowing into wetlands and the stream, from the headwaters to the mouth;

(2) wetlands (peatlands in particular) that provide essential nutrients and store and contribute adequate amount of water to the stream;

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[105] Price, J. S., R. G. McLaren and D. L. Rudolph. 2010. Landscape restoration after oil sands mining: conceptual design and hydrological modelling for fen reconstruction. International Journal of Mining, Reclamation & Environment, 24:109-123.

[106] Gorham, E. and L. Rochefort. 2003. Peatland restoration: A brief assessment with special reference to Sphagnum bogs. Wetlands Ecology and Management, 11:109-119. Table 4, page 115.

[107] Quinty, F. and L. Rochefort. 2003. Peatland Restoration Guide, second edition. Canadian Sphagnum Peat Moss Association and New Brunswick Department of Natural Resources and Energy, Québec, Québec.106 pp. Page 12.

[108] Farrell, C. A. and G. J. Doyle. 2003. Rehabilitation of industrial cutaway Atlantic blanket bog in County Mayo, North-West Ireland. Wetlands Ecology and Management, 11:21-35. Page 33.

[109] Ibid, page 17

[110] Schumann, M & M Joosten. 2008. Global Peatland Restoration Manual. International Mire Conservation Group, Griefswald, Germany. Page 22. Available at: http://www.imcg.net/pages/topics/projects/global-peatland-restoration -manual.php?lang=EN

(3) a dynamically stable stream channel, which provides and renews suitable spawning and rearing habitat for adult and juvenile salmon;
(4) marine derived nutrients from an adequate supply of returning adult salmon;
(5) a flood plain and associated riparian vegetation, which provides food web interaction, stream bank stability, adequate capacity to store flood waters and cover for rearing salmonids, including velocity refugia during floods; and
(6) complex aquifers, which exchange essential, good quality, hyphoreic and phreatic ground water flow to maintain salmon redds and rearing habitat, particularly in the winter when surface flow is minimized and air temperatures fall below freezing.

Failure to consider and successfully re-create each of the landscape elements of Middle Creek, Lone Creek and Stream 2004 in ways where they successfully interact with other environmental elements would result in failure to re-create a functioning salmon spawning and rearing stream systems.[111, 112, 113, 114, 115] The baseline studies provide insufficient information to understand the end points of building landscape elements and re-creating their interaction. However, if that information is collected, such a construction endeavor would be nothing more certain than an experiment in restoration. Today's level of expertise is far from that needed to rebuild the complexity of a salmon-supporting watershed such as the Chuitna River.

5 CONCLUSION

The sum of the conclusions of the scientific reviewers, each of whom analyzed material in their respective field, is that the Chuitna Watershed in the proposed mine area is too complex to be re-created given the extent of damage anticipated from mining.

A functioning salmon-producing watershed at anything near today's ecosystem productivity cannot be constructed at a site disturbed to the extent proposed in the Chuitna system. In particular, the interaction of the groundwater system with surface water features, including streams and wetlands, is key to building a salmon based ecosystem. The interface of complex inter-bedded geologic substrate with stream channels creates habitat features that will be lost when materials are excavated, mixed and replaced. Greater permeability of backfilled materials will result in groundwater draining more quickly, leading to higher flows for shorter portions of the year and little or no groundwater discharge high in the watershed.

Peat dominated wetlands play another key role in maintaining baseflow through dry winter and summer periods but, according to current understanding, cannot be restored once disturbed. Important wetland functions, baseflow support in particular, will be lost at least for the millennia it will take for them to form.

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[111] Bernhardt, E, and M. Palmer. 2011. River restoration: The fuzzy logic of repairing reaches to reverse catchment scale degradation. Ecological Applications. 21(6)2011, pp 1926-1931.
[112] Jahnig, S., A.Lorenz,D. Hering, C. Antons, A Sundermann, E. J. Jedicke, and P. Haase. 2011. River restoration success: a question of perception. Ecological Applications. 21(6)2011 pp2007-2013.
[113] Filoso S., and M. Palmer. 2011. Assessing stream restoration effectiveness at reducing nitrogen export to downstream waters. Ecological Applications. 21(6)2011pp1989-2006.
[114] Loughi, P, H.Mykra, R. Paavola, A Huuusko, T. Vehanen, A. Maki-Petays and T. Muotka. 2011. Twenty years of stream restoration in Finland: little response by benthic macro invertebrate communities. Ecological Applications. 21(6)2011pp1950-1961
[115] Violin,C.,P. Cada, E. Sudduth, B. Hassett, D. Penrose, and E. Bernhardt. 2011. Effects of urbanization and urban streams restoration on the physical and biological structure of stream ecosystems. Ecological Applications. 21(6)2011pp 1931-1949.

Past efforts have met limited success at re-creating stream ecosystems even in locations where site hydrology exists to support the stream. Never has there been an attempt to re- create a salmon-supporting stream channel in a brand new watershed complete with a constructed multi-aquifer groundwater system, flood plains and wetlands. In spite of efforts to replace site topography, stream channel form and sites for wetlands, the post mining landscape will function very differently and likely cannot support the productive salmon-based ecosystem that exists today.

The mining of LMU1 would be the beginning of mining of nearly the entire Chuitna River Watershed. If mining LMU1 proves profitable then mining in the LMU2 and LMU3 areas, which would include excavating the mainstem of the Chuitna River and additional tributaries, can be anticipated. Further mining by the Beluga Coal Company, who owns coal leases adjacent to PacRim's leased areas can also be anticipated, and would lead to further excavation of the Chuitna Watershed. While the adverse effects on aquatic resources of mining a single Chuitna River subwatershed would be significant, the adverse effects of mining multiple watersheds in this system would be many times worse.

Appendix A

The following scientists reviewed baseline information collected from the Middle Creek watershed, along with other relevant scientific literature, and analyzed the likelihood of successful ecological re-creation:

Margaret Palmer, PhD. – Professor at the University of Maryland and Executive Director of the National Socio-Environmental Synthesis Center. Dr. Palmer has 30 years of experience in research and teaching on coastal ecosystems, watershed science, and stream ecology and restoration. Past work includes leading a large team of scientists in developing the first national database on river restoration in the U.S., co-authoring a book entitled The Foundations of Restoration Ecology, and serving as an expert advisor on the design of multiple stream and river restoration projects.

Mark Wipfli, PhD. – Professor of Freshwater Ecology, University of Alaska, Fairbanks, Assistant Leader, Alaska Cooperative Fish and Wildlife Research Unit. Previously he was a research ecologist at the USDA – Forest Service, Pacific Northwest Research Stations at Wenachee, Washington and Juneau, Alaska. Dr. Wipfli's published research addresses processes that govern freshwater-riparian productivity, spatial subsidies in freshwater food webs, linkages between freshwater-marine and freshwater-terrestrial ecosystems, salmonid foraging ecology and trophic interactions, invasive species impacts in freshwater/riparian ecosystems, climate change effects on freshwater food webs, restoration and management of freshwater and riparian ecosystems.

Lance Trasky – Former Regional Supervisor, Alaska Department of Fish and Game, Habitat Division Southcentral Alaska, Retired, with 32 years' experience as a fisheries and habitat biologist. Mr. Trasky is an expert on the ecology of salmon in Southcentral Alaska. He spent his career reviewing development proposals for their likely effect on salmon streams and prospects for restoration.

Barry Hecht – Senior Principal at Balance Hydrologics, San Francisco, CA. Mr. Hecht has been consulting for more than 45 years in many areas of habitat hydrology, hydrogeology and geomorphology. He previously served as Chief Hydrologist/Geologist with Kleinfelder and H. Esmaili & Associates, and served with U.S. Geological Survey and U.S. Forest Service research groups. Mr. Hecht taught for 3 years at UC Santa Cruz and lectures regularly at UC Berkeley.

Tim Bartholomaus, PhD. – Balance Hydrologics. Dr, Bartholomaus' most recent work at the University of Alaska, Geophysical Institute, focused on glacial dynamics. He is now a post-doctoral fellow at University of Texas, Institute for Geophysics.

Tom Myers, PhD. – Hydrologic consultant, Reno, Nevada. Dr. Myers has 28 years of experience as a consultant, government planner, academic researcher and teacher. His work includes major hydrology studies for the federal government, hydrogeologic assessments for county governments, expert and evidence reports for use in litigation and administrative hearings, and expert witnessing for private industry and nonprofit groups.

Mitchel Swanson, PhD. – Geomorphologist, River Restoration Scientist, Swanson Hydrology and Geomorphology, Santa Cruz, California. Dr. Swanson has over eighteen years of experience in hydrology, hydraulic studies, geologic hazards, and geomorphology related to restoration and resource management in rivers, streams, coastal estuaries, and wetlands. This experience includes the development, management and completion of comprehensive technical and planning studies for a full range of private and public sector clients. Dr. Swanson specializes in the development of technically and environmentally sound management and restoration plans for rivers, estuaries and watersheds.

Kendra Zamzow, PhD. – Dr. Zamzow (Chickaloon, Alaska) is an environmental geochemist for the Center for Science in Public Participation, specializing in mine water chemistry. Dr. Zamzow is also an associate editor for the journal Mine Water and the Environment.

Bill Hauser, PhD. – Dr. Hauser is a fish biologist retired from the Alaska Department of Fish and Game after 22 years. He is the author of Fishes of the Last Frontier and Letters from Alaska. Dr. Hauser currently writes a column for the Alaska Fly Fishers newsletter called Fish Talk were he discusses various aspects of fish biology, ecology, and life histories in a nontechnical language.

Mike Gracz – Mr. Gracz is a wetland ecologist working for the Kenai Watershed Forum from Fritz Creek, Alaska. He is the primary author of a wetland classification system that describes the geomorphic setting and functions of wetlands in the Cook Inlet Basin. Mr. Gracz has mapped most the wetlands on non-federal lands on the Kenai Peninsula and portions of the Matanuska-Susitna Basin. As a graduate student at the University of Minnesota, he has completed research with the EPA Mid-Continent Ecology Division Laboratory on biogeochemistry and hydrology of Cook Inlet Basin wetlands.

We also relied upon Comments on the Revised Draft Water Management Plan Chuitna Coal Project (Tetra Tech, March 2013) and Associated Documents by Robert Prucha, PhD. and others at Integrated Hydro Systems, LLC, Boulder, Colorado, and the Wilderness Society. This study was commissioned by the U.S. Fish and Wildlife Service.

Finally, this summary document was reviewed, with contributions, by:

Mark Rains, PhD – Associate Professor of Geology, University of South Florida. Professor Rains' research includes ecohydrology, hydrogeology, wetland, river, and coastal ecosystem structure and function. Professor Rains has extensive experience researching the hydrology of wetlands in Southcentral Alaska, and has provided research on the Pebble Prospect in Southwest Alaska.

Alexander Milner, PhD – Professor of River Ecosystems at the University of Birmingham, United Kingdom and Professor of Aquatic Biology at the University of Alaska. Professor Milner's research involves river ecosystems in alpine and Arctic environments and has long term studies on salmon colonization in Glacier Bay National Park and stream ecology in Denali National Park in Alaska. He worked on the Red Dog Mine project in northwest Alaska and placer mining issues in interior Alaska.